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THOR/EMILY

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1. Introduction: The THOR program was initiated by a Department of Defense Directive in late November 1955. It was assigned to the Air Force at a time when our national leaders were seriously concerned by the vigorous program which the Soviet Union had been carrying out in short and intermediate range ballistic missile programs. There was also at that time very serious concern regarding the long lead times and long development cycles generally experienced in our country with major weapon systems (reference the Robertson Committee Report). The decision was made, therefore, in late 1955 to attempt the all-out compression of a complete development cycle from program initiation to operational deployment. Attachment #1 is a condensed chronology of Operation Emily, an RAF nickname given the deployment of THOR to the United Kingdom.

a. Traditional Development: In the post-World War II era, development of a major weapon system was a series of operations. There were 5 steps which were initiated sequentially. Studies would take place, after which development would occur, followed by flight test, full scale production, and then training and operational activation. The complete time for this development cycle had been 8 to 12 years. To drastically shorten this time period, it was necessary to conduct development, test, production, training and operational activation in parallel.

b. THOR Concurrency: The THOR program was started on 27 December 1955. AFBMD's first step was to take the actions required to design, develop and fabricate the missile and associated ground support equipment in preparation for a first launch within 12 months. In 1957, the R&D test program continued, culminating in a Weapon System Development Engineering Inspection in December 1957. In the Spring of 1957, plans with SAC and ATC for the training programs were made and items of R&D equipment were acquired for use in individual training. IOC (Initial Operational Capability) facility design was started in the Spring of 1957. By the middle of 1958 the first IOC missile at AMR

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(Atlantic Missile Range) was launched, individual training was being performed, and 1st Squadron facilities were being constructed. Also at that time, preparations were made to test weapon system ground support equipment (GSE) at the Sacramento, California, Test Facility, and missiles and GSE were being produced at the rate required for the IOC force. Under these conditions, the THOR United Kingdom deployment was initiated. On 22 April 1960, the fourth and last squadron was turned over to the RAF. The "Concurrency Concept" in the THOR program most surely had paid off. (Attachment 2).

## 2. The New Job

The 1955 decision to attempt all-out development cycle compression presented a double challenge: Not only did the THOR system require further technical advancement in the missile art itself, but also it was necessary at the same time to create from scratch the operational environment for the ballistic missile as a weapon. New aircraft systems can generally use established runways, control towers, and many other existing installations. Not so with the ballistic missile. The challenge of shortening the THOR development cycle lay in simultaneously creating a new ground environment, new facilities and equipment, and a new operational force, while also creating a new missile. Add to this the complexity of overseas deployment during the same period and some appreciation can be gained concerning the scope of the task undertaken and successfully accomplished by the Air Force and its team of industrial contractors, in spite of major program fluctuations. The THOR program was inaugurated by the Douglas Aircraft Company in December 1955 when Douglas was selected to be the IRBM airframe contractor for a 1500 NM missile which was to be deployed in the field at the earliest possible time. All the key program goals were met and many on dates that were even earlier than had been anticipated. That <sup>t</sup>is was done so well verifies the essential soundness of the Air Force development-management team and of the concurrency concept.

3. The THOR Missile: To meet the earliest possible dates, heavy borrowing was done from the ATLAS Program which had been started earlier. The General Electric THOR nose cone is almost identical to the GE heat sink nose cone used for the ATLAS missile. The THOR's Rocketdyne engine was borrowed from the ATLAS booster which was then already under development. The AC Spark Plug all-inertial guidance system under development for ATLAS was re-oriented to THOR. Many vital components in the electrical, hydraulic and pneumatic systems were also shared with ATLAS. Confidence in these building blocks permitted an early all-out start in the THOR program.

The THOR missile grosses approximately 110,000 pounds, of which more than 90% are propellants. The engine develops a thrust of 150,000 pounds. Two vernier engines of 1,000 pounds each are used for roll control and for final velocity determination. The guidance system is all-inertial and has a design specification requirement of 2 NM CEP. The missile itself had a range specification requirement of 1500 NM. These missile performance goals, established in 1955, are met or bettered by the missiles that are currently deployed in the operational force.

4. Ground Support Equipment: There are 15 missiles in the THOR Squadron. These missiles are contained in 5 positions, each of which have 3 missile emplacements in close proximity to each other. The 3 emplacements are controlled from a centralized launch control area. The concept in designing the GSE was to achieve a movable and dispersable system that would have a minimum reaction time. The goal was set for a reaction time of 15 minutes from instant of command to lift-off. Equipment currently deployed to the UK has a reaction time of between 15 and 20 minutes, and with approved engineering changes is expected to achieve a salvo capability. This capability has been vividly demonstrated by conducting complete wet simultaneous countdowns in 19 minutes for an entire position containing 3 missiles.

The THOR countdown consists of 5 phases. Some of the important actions are:

- Phase I: Generators start  
Guidance System starts alignment  
Control electronic system is turned on  
Engine and propellants systems are enabled
- Phase II: Shelter moves back approximately 95 feet to clear missile  
Missile erects to vertical
- Phase III: Fine load of RP-1 and LOX proceeds
- Phase IV: Rapid load of RP-1 and LOX proceeds
- Phase V: Clamshells are opened and erector is released  
Erector lowers to horizontal rest position  
Power is shifted from ground to missile  
Nose cone has been enabled  
Battery activates  
Shelter moves to full retract position  
Lift-off is accomplished

Note: Launch control officer can stop the automatic countdown up to  $\frac{1}{2}$  second prior to lift-off.

5. Various Definitions of IOC: The first definition of an operational program was in January 1956, when a 64 missile R&D program was authorized, calling for an initial operational capability (IOC) in January 1960. The November 1956 Development Plan, which was the first official development plan, called for a total of 4 THOR Squadrons, with the 1st Squadron operational date to be July 1959. In mid-1957, during the THOR-JUPITER evaluation, IOC plans were suspended and the program was cut back to a production rate of 2 per month. Then in December 1957, an IOC program was authorized for planning purposes only, calling for a 1st Squadron operational date in December 1959. Later that month, U.S. Air Force, by DOD Directive, was directed to deploy the 1st Squadron in December 1958. Subsequently, in lieu of deployment, AFBMD was directed to make the 1st Squadron operational. Chronology of these directives follows:
- Jan 56 65 Missile R&D Program culminating in an "operational capability in January 1960
  - Nov 56 4 Squadrons planned with 1st Squadron operational in July 1959
  - Aug 57 IOC Plans suspended pending THOR/JUPITER Decision
  - Dec 57 IOC Planning authorized for 4 Squadrons - 1st Squadron operational in December 1959
  - Dec 57 USAF directed to deploy 1st Squadron in Dec 1958.

6. THOR Missile Summary: The final THOR Program called for a 4-Squadron Program and a schedule which will be discussed in greater detail in paragraph 8 below. There were a total of 224 missiles assigned to the THOR program, of which 60 have been used in the R&D Program, 71 were earmarked to special projects (DISCOVERER, ABLEs, TRANSIT, etc.), 60 are assigned to the operational force, 13 have been assigned to the Integrated Weapon System Training (IWST) Program, and 20 missiles are scheduled for the Confidence Training Launchings (CTL). The last THOR missile for any of the above applications is scheduled for production completion in early 1961.

7. Changed Conditions: In the December 1957 plan which proposed to meet a December 1958 deployment date, higher headquarters recognized certain weapon system limitations would be necessary. This plan recognized a probably degraded operational capability; that prototype equipment could be used where full production equipment would not be available; that there would be informal turnover procedures, and that formal technical data would not be required. Consideration was given to USAF manning with heavy support by contractor force.

#### CONDITIONS FOR INITIAL DEPLOYMENT

##### Dec 1957 Agreements

Degraded operational capability acceptable

Prototype equipment could be used

Informal turnover procedures

Informal data requirements

USAF manned

##### Criteria Required in 1958-60

Full operational capability required

Formal configuration control on operational equipment

Formal administrative procedures and weapon systems operability demonstrations required

Verified technical manuals

RAF manned

The change of IOC responsibility from ARDC to SAC and field experience later dictated that the equipment furnished the UK have a full operational capability. Operational equipment was used exclusively and was under formal configuration control. Formal administrative turnover procedures, including

weapon systems operability demonstrations, were necessary conditions for turnover to the RAF. Verified technical manuals were placed in the field organizations concurrently with the squadrons, and the RAF is manning the squadrons. In summary, certification of the operability of a missile system requires careful attention to detail, accurate documentation, and successful demonstration -- a marked contrast from the planning criteria of little more than one year previous.

8. United Kingdom Schedules: The first official site activation schedule was prepared in April 1958. Its operational dates were as follows:

|                  |             |
|------------------|-------------|
| 31 December 1958 | Squadron #1 |
| 30 June 1959     | Squadron #2 |
| 31 October 1959  | Squadron #3 |
| 31 March 1960    | Squadron #4 |

Several factors contributed to missing this initial forecast. Among these were weather, difficult equipment delivery, facility problems and lack of early recognition of the magnitude of the total squadron activation problem. These factors caused a revision of the schedule and of the November 1958 Development Plan to Hq USAF. During the winter of 1958-59 the schedule was re-assessed based on the experience being acquired. As a result, a firm contract schedule was negotiated with Douglas Aircraft Company in February 1959. During the summer of 1959, there were additional minor slippages in facilities for Squadrons #3 and #4, which caused a revision of this contract schedule. The final schedule is shown by the right-hand solid line on Attachment #3. The actual contract turnover dates of each squadron can be seen. The fourth squadron was turned over 3 weeks ahead of the final schedule, on 22 April 1960 (See Attachments 1 and 4).

It should be kept in mind that this was a first-time program for a weapon system of unique type and complexity. The various difficulties involved in placing a weapon system that was essentially in the R&D phase of development into the field on a compressed time scale became more evident during efforts to put the four THOR Squadrons into operation in England.

In spite of those problems, when the short time spent is considered, the Air Force and the responsible contractors achieved a remarkable accomplishment.

9. Lessons of Experience: The lessons learned have been fed back to the responsible management groups on the ATLAS, TITAN and MINUTEMAN programs, and should materially assist in avoiding many delays in those programs. The first Douglas work contingent arrived in the United Kingdom in July 1958. Many of these personnel were new to the THOR program, and had only the slightest introduction to the system. Early program management was not sufficiently prepared or manned to cope with a job of this scope -- and, in fact, the scope of the problem was not fully clear in those early phases. The fact that many engineering modifications were required created difficulty. Supplies were sometimes late in arriving and damages occurred to some key and delicate items during sea shipment. To these problems were added the various other headaches associated with moving civilian family groups into a foreign country. Therefore, by October 1958 the schedule had slipped badly and the program seemed in difficulty. In spite of this condition, concerted effort on the part of Air Force and contractor personnel enabled us to have seven missiles in position by the end of the year. The lack of adequate resources in the form of equipment, information, and engineering and management personnel led to troubles in the checkout phase following the relatively simple installation phase which preceded it. As a result, a detailed status control room was pressed into service as a management tool to pinpoint critical problem areas. Daily and weekly meetings were held to bring all available resources into focus. By January 1959, the Douglas Company was well aware of the problems being encountered in the field, and aggressively went to work to correct deficiencies. Early in 1959, a complete reorganization of the Douglas UK Division was accomplished and a team of experienced engineering, management and checkout personnel was brought in, led by Mr. William L. Duval, who assumed management of the contractor effort.

The normal pattern of I&C operation soon began to emerge from the problems of errors, modifications, logistic and other aspects of system deployment. It was evident to the new management that a system of rapidly honoring I&C supply, logistic, and personnel requirements, together with a feedback to California of technical information generated in the UK, was required. Once established, the system paid immediate dividends. Modification packages, many derived directly from earlier experience in the UK, began to arrive. Additional personnel, a very critical resource in the program, were added to the existing force to support the strenuous working schedule being performed. Additionally, equipment being delivered contained more and more factory-accomplished modifications, thereby reducing the workload further. These improvements, coupled with a generally improving weather picture, gave an overall lift to morale and a corresponding increase in efficiency. Time periods required to perform certain I&C tasks were dramatically reduced and the quality of workmanship noticeably increased. As an example, in the early days several attempts were often required to perform successfully a task such as the functional demonstration of launch countdown sequence. Later, it was accomplished routinely in the first attempts. Simultaneously successful multiple countdowns provided an outstanding example of the improved performance of military and contractor personnel.

10. Configuration Control: Prior to a discussion of the Modification Program, identification of the configuration control used in the THOR Program should be made. In September 1958 configuration was frozen. By a directive signed by the Commander, AFBMD, it was stated to all contractors that no further changes would be approved except those required for minimum system requirements and for safety. A Configuration Control Board was established, chaired by AFBMD and with representatives from AMC, SAC, and the RAF. This Board was the final approving authority for all proposed changes. Prior to its full operation, a firm configuration definition by specifications was needed. By December 1958, such a definition was determined for the Douglas Aircraft Company ground support

and missile equipment. By February 1959, the same determination was finished for the equipment of the other three subsystem associate contractors. Taking into consideration the results of the R&D flight test program at AFMTC, the GSE test program at Sacramento, results of the training program at Vandenberg, and the initial deployment equipment in the UK, a definition was made of a Modification Program that would be required on UK equipment. This Modification Program would insure that all of the equipment in the UK would meet system requirements and be of the same logistically supportable configuration.

#### CONFIGURATION CONTROL

##### Key Dates

##### Chronology

|                               |  |
|-------------------------------|--|
| September 1958                | Configuration Freeze - "No further changes except those required for minimum system requirements or safety." |
| December 1958 - February 1959 | Complete missile and GSE configuration definition  |
| April 1959                    | Definition of Modification Program   |

11. Modification Program: The bulk of the modification effort was required for Squadron #1. Squadron #2 required approximately 40% of the effort required for Squadron #1. The Modification Programs for Squadrons #3 and #4 were trivial since the changes were already incorporated in production. The cost of the Modification Program was approximately \$1.7 Million in a program valued at over \$900 Million (See Attachments 5 and 6).

12. THOR Program Funds: Attachment #6 shows the amount of money spent on the THOR Program. When concluded, the USAF will have spent approximately \$953 Million. For the big years, the average rate of expenditure was in excess of \$200 Million a year. The total cumulative cost of installation and checkout and Modification Program is also shown in this chart. Approximately \$35 Million was spent for this effort. It is evident that the early completion of the program afforded savings that were many times more than the total installation and checkout program, of which the Modification Program was only an extremely small portion. In comparison to a monthly industrial

force activity cost which averaged \$20 Million, the modification cost of \$1.7 Million is rather slight. By completing the THOR Program in 4 years, appreciable savings have been afforded the U.S. Government. This early program completion could only have been accomplished under the principles of concurrent development, test, training, production, and deployment. The necessary Modification Program which ensued was very small compared to the total cost involved: - a financial value cannot be placed upon a deterrent force of 60 missiles in the field a matter of years earlier than would have otherwise been required.

13. Magnitude of Transportation and Logistics Requirements:

(AIRLIFT)

| <u>Shipped From</u>                          | <u>Dates</u>              | <u>Trips</u> | <u>Pounds</u> |
|--|---------------------------|--------------|---------------|
| Long Beach, California                       | 1 Aug 58 -<br>22 Feb 60   | 504          | 18,900,000    |
| Santa Monica, California<br>(Missiles)       | 24 Jan 59 -<br>1 Aug 60   | 65           | 936,261       |
| Cummins-Diesel, Indiana                      | 28 Jul 58 -<br>23 Nov 59  | 22           | 648,000       |
| Ford Machinery Corp,<br>San Jose, California | 31 Jul 58 -<br>30 Sep 59  | 51           | 1,269,669     |
| Cambridge Corp., Massachusetts               | 10 July 58 -<br>13 Jan 60 | 37           | 1,235,800     |
| TOTAL  |                           | 679          | 22,989,730    |

NOTE: Column entitled "Trips" represents airlift.

|   |                   |
|---|-------------------|
| Total log sea tonnage - New York and Long Beach | <u>18,214,610</u> |
| GRAND TOTAL - Airlift and Log Sea               | <u>41,204,340</u> |

14. Number of Wet and Dry Countdowns: Wet and dry countdown exercises perform two essential functions in the fielding and maintenance of the weapon system. First, the contractor uses wet and dry countdowns during I&C as part of the functional design requirement testing and validation process. Douglas performed, during the I&C period, the following number of countdowns:

|            | <u>1st Sqdn</u> | <u>2nd Sqdn</u> | <u>3rd Sqdn</u> | <u>4th Sqdn</u> |
|------------|-----------------|-----------------|-----------------|-----------------|
| Wet Counts | 52              | 33              | 24              | 32              |
| Dry Counts | 165             | 95              | 51              | 54              |

Secondly, and perhaps the most important function, are the countdowns used for training the operational force. During the period June 1959 to 30 June 1960, the RAF accomplished the following:

|            |     |     |     |     |
|------------|-----|-----|-----|-----|
| Wet Counts | 15  | 15  | 15  | 15  |
| Dry Counts | 500 | 400 | 250 | 100 |

The RAF accepted the first operational position of 3 missiles at Squadron #1 for a training location with reduced operational reaction times, and in addition to the wet and dry countdowns indicated above, have accomplished:

|            |     |
|------------|-----|
| Wet-Counts | 3   |
| Dry Counts | 300 |

15. General Problems: Much was learned from the installation and checkout activities and was applied to the ATLAS, TITAN and MINUTEMAN ICBM programs. The types of problems often were related to the newness of the task. THOR was the first ballistic missile to be deployed. Pressure was extreme, with directed schedules calling for earliest possible operational activation. Equipment had to be transported 6,000 miles from the ZI to the UK. Contractor and military forces had to build up to participate in installation and checkout and in all phases of site activation. Up-to-date specifications and technical data were required in the field. The job was a big one, calling for a tremendous amount of concentrated effort in a relatively

short period of time. Last of all was the problem of weather. The first winter in the UK was extremely difficult for the contractor force.

16. Organizational Problems: In the UK deployment, the first step was to establish Douglas as the integrating contractor to tie together the activities of the other associate contractors. The ballistic Missile European Field Office was also established, with representation from AFBMD, BMC, and SAC-MIKE. AFBMD had the task of having to correlate the activities of many agencies that were involved in site activation. Having the base of operations 6,000 miles from the production source did not help. Missions had to be clearly defined and the responsibilities and relationships of all agencies concerned had to be "blueprinted". Specialized site activation and installation and checkout planning schedules had to be established, as were control and reporting schedules. Also essential was the organization of the methodology required to react quickly on technical as well as other problems.

17. Personnel Logistics: It was recognized early in the deployment that a contractor force in excess of what was previously planned was needed. There were problems of housing for this contractor force, and to meet this problem house trailer camps for contractor personnel were established at each squadron. Contractors were also permitted the use of base housing, AFEX, and Officers Clubs, particularly in remote locations. In the critical months in late 1958, the European Field Office was augmented with temporary duty AFBMD personnel from Inglewood. Through the first winter, 60% of the contractor force became incapacitated at various times with influenza.

Buildup of Douglas Aircraft Company Personnel

|           | <u>1958</u> | <u>1959</u> | <u>1960</u> |
|-----------|-------------|-------------|-------------|
| January   |             | 576         | 676         |
| February  |             | 621         | 624         |
| March     |             | 687         | 492         |
| April     | 4           | 833         | 389         |
| May       | 24          | 872         | 276         |
| June      | 68          | 859         | 146         |
| July      | 181         | 886         |             |
| August    | 312         | 874         |             |
| September | 376         | 842         |             |
| October   | 389         | 795         |             |
| November  | 405         | 769         |             |
| December  | 495         | 733         |             |

After much negotiation UK Nationals were also integrated into the site activation (I&C) team. The overall picture at the peak loading in August 1959 was:

|                  |                           |
|------------------|---------------------------|
| Douglas Aircraft | 874 plus 109 UK Nationals |
| AC Spark Plug    | 78                        |
| Rocketdyne       | 82 plus 14 UK Nationals   |
| General Electric | 21 plus 3 UK Nationals    |
| Total            | 1181                      |

18. Failure and Consumption Data Reporting: The THOR IRBM weapon system was not only the first USAF ballistic missile to be operationally deployed, but its history also shows that several new management concepts and administrative and logistic support systems were developed. One of these systems generally called "AFIO 120 System" was one developed to afford support of the logistic administration. In essence, T.O. 35D-34 was modified by adding a Section V for application only to ballistic missiles. Several forms were developed to accomplish failure reporting, consumption information, reparable part information, and failure analysis data. The form 120 was used/in the 1957-1959 period to report all sorts of occurrences. These reports included replacement part data, technical manual data, equipment deficiencies, and failed parts information. Essentially the requirement was that any time anything happened to the equipment in the operator's hand, a form 120 had to be submitted before a replacement part was issued, etc. This substitute for the "UR" system was supported by the electronic data processing equipment (EDPE) at SBAMA. Experience has shown the Hollorath (RAF) system to be more easily used on the THOR, and it is replacing the USAF system. Under this system only those failure reports requiring action by SBAMA will be forwarded by Bomber Command in the UK.

Some concern has been expressed that approximately 12,400 AFTO 120 reports had been received at SBAMA during the period June 1959 to June 1960. Of this number 246 were Priority #1 (requiring immediate attention), 391 were Priority #2, and 11,741 were Priority #3. Of this group, approximately 16 Materiel Improvement Programs (MIP) were required for Priority #1, 48 for Priority #2, and 629 for Priority #3. Approximately 10% of the AFTO 120's submitted were directly attributed to the environmental conditions in the deployment area. There are 79 THOR missiles and 8,100 major GSE end items reported under SBAMA's logistic jurisdiction. To appreciate the relatively small magnitude of the AFTO 120 reports in the THOR program in comparison with experience in other programs, it is interesting to note that on the C-124 aircraft program SBAMA receives approximately 90,000 reports per month and that in the C-133 aircraft program 11,000 failure reports are received each month.

19. THOR Operational Schedules: Despite the greatly changed criteria of the total operational force compared to initial premises in December 1957, and taking into consideration British-constructed facilities delays, there is not appreciable difference between the actual squadron completion dates and the initial December 1957 projection. The 4th Squadron, scheduled for turnover on 13 May 1960, was actually given to the RAF on 22 April 1960, compared to a December 1957 projection of March 1960. The 3rd Squadron was turned over in December 1959, compared to initial projection of 31 October 1959. The 2nd Squadron was turned over in September 1959, compared to initial projection of 31 July 1959. The 1st Squadron was turned over in May 1959, compared to initial projection of 31 December 1958. It was only  $3\frac{1}{2}$  years from program initiation to the turnover of the 1st Squadron, which represents a time saving of some two and one-half years over that possible under previous traditional development approaches. This time saving not only represented a vast sum of money, but saw an operational force fielded at an early date.

Timing of Site Activation of All Squadrons in UK

|             |           |
|-------------|-----------|
| Squadron #1 | 137 Weeks |
| Squadron #2 | 87 "      |
| Squadron #3 | 55 "      |
| Squadron #4 | 63 "      |

20. Program Accomplishments: Summary of major accomplishments of the THOR starting in December 1955 and ending in the early summer of 1960 follows:

| <u>ITEM</u>                                      | <u>DATE</u>     |
|--|-----------------|
| Contractual Go-Ahead                             | 23 Dec 1955     |
| Contract Signed                                  | 27 Dec 1955     |
| First Flight                                     | 25 Jan 1957     |
| Maximum Range Demonstration (over 2300 miles)    | 24 Oct 1957     |
| Weapon System Development Engineering Inspection | 2 - 17 Dec 1957 |
| First Guidance Flight                            | 7 Dec 1957      |
| First Reentry Vehicle Flight                     | 28 Feb 1958     |
| Delivery First IOC Configuration Missile         | 31 May 1958     |
| First Launch from IOC Launcher                   | 4 June 1958     |
| First Successful Warhead Flight                  | 26 Nov 1958     |
| Demonstration Launch at Vandenberg AFB           | 16 Dec 1958     |
| Turnover 1st RAF Squadron                        | 22 June 1959    |
| Turnover 2nd RAF Squadron                        | 11 Sep 1959     |
| First CTL Flight                                 | 6 Oct 1959      |
| THOR Weapon System Declared Operational          | 12 Dec 1959     |
| Turnover 3rd RAF Squadron                        | 21 Dec 1959     |
| Delivery of 200th Missile                        | April 1960      |
| Turnover 4th RAF Squadron                        | 22 Apr 1960     |
| 100th Missile Flight                             | August 1960     |